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PROJECT 0254: PLASMA THERMIONIC DIODES

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The purpose of this project is to study the randomization of electron energies in thermionic diodes by computer methods.

We summarized the results obtained for the low-pressure (collisionless) one dimensional thermionic converter.

When the separation between the emitter and collector plates is larger than ten electron Debeye lengths, the operation of the diode is determined essentially by two parameters:

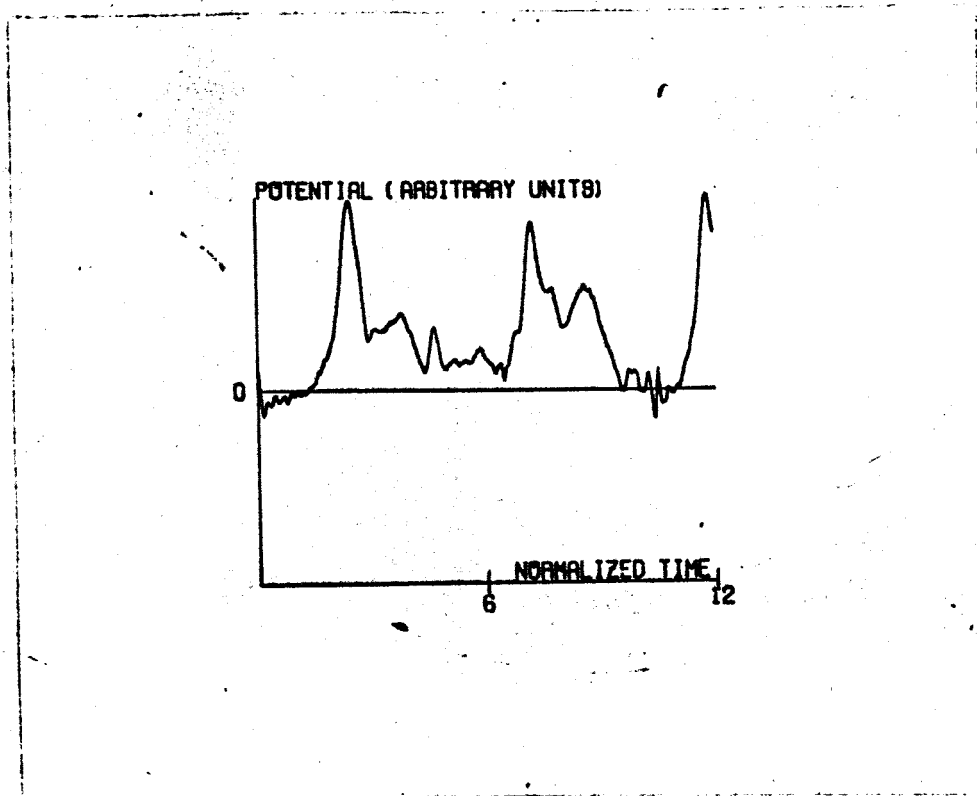
1. The ratio of charge densities near the emitter called $\alpha = J_{si} m_i / J_{se} m_e$, where J_{si} , J_{se} are the saturation currents of the ions and electrons respectively and m_i , m_e are their respective masses.
2. The applied potential, which has the normalized form $\eta_2 = eV_2 / kT$ where V_2 is the applied potential in volts, and T is the emitter temperature.

Depending whether η_2 is positive or negative and α is larger or smaller than unity we define four operating regions. The stable or unstable behavior of the diode can be demonstrated by plotting the potential as function of time at some point in the diode. This corresponds to an ideal probe inserted into the diode space. We plot the potential for the four regions on Figs. 1 - 4 at a point which is approximately ten electron Debeye lengths from the emitter. We expect the fluctuations to be the largest here, because this point is in the general neighborhood where a potential minimum (for the electron rich case) or a potential maximum (for the ion rich case) is formed. The simulated converter is fifty electron Debeye lengths long. On these figures time is normalized to the average electron transit time and since the ratio of ion to electron mass is 64, the average ion transit time is eight times the average electron transit time. The scale of the potential axis is in arbitrary units because the actual value of the potential depends on the applied potential and we are interested here only in the general behavior of the diode. This behavior depends only on whether the potential is positive or negative and not on its actual value.

In the first region ($\eta_2 > 0$, $\alpha > 1$) the converter exhibits large amplitude, low frequency oscillations (see Fig. 1). The frequency of these oscillations is approximately equal to one over the average ion transit time, and thus can be easily detected in cesium diodes which operate in this region. We have studied these oscillations in details and reported results in earlier QRR's. The diode operating in the second region, ($\alpha > 1$, $\eta_2 < 0$) exhibits high frequency oscillations (see Fig. 2). It is difficult to observe these fluctuations in a cesium diode because their frequency is of the order of the electron plasma frequency near the emitter, i.e., thousands of megacycles and the amplitudes are small (typically a tenth of a volt). Nevertheless the computer simulation technique shows that the diode will be noisy in this region.

If the converter operates in the third region ($\eta_2 > 0$, $\alpha < 1$) a true potential minimum is formed near the emitter which limits the electron current flowing in the diode below its saturation value (see Fig. 3). The fluctuations become small--though there is a trace of collective oscillations with ion frequency--and apparently the operation of the diode is stabilized. The stabilization is increased by applying negative voltage to the collector (see Fig. 4). In this region ($\eta_2 < 0$, $\alpha < 1$) the fluctuations are due only to shot noise effects and are of negligible amplitude. These calculations indicate that an extremely quiet and stable plasma is created in a cesium diode when it operates in the electron rich region with a negative bias on the collector. The results are summarized in Table 1.

We are considering the expansion of the computer simulation procedure at the present. We will introduce surface effects at the emitter (changing work functions for ions, electrons as functions of cesium coverage), elastic collisions for ions and electrons with neutrals and volume ionization processes. These additions to the existing computer simulation technique will enable us to simulate the operation of a real thermionic converter much better than with the collisionless technique.



**FIG. 1. POTENTIAL FLUCTUATIONS NEAR THE EMITTER
WHEN $\alpha > 1$, $\eta_2 > 0$.**

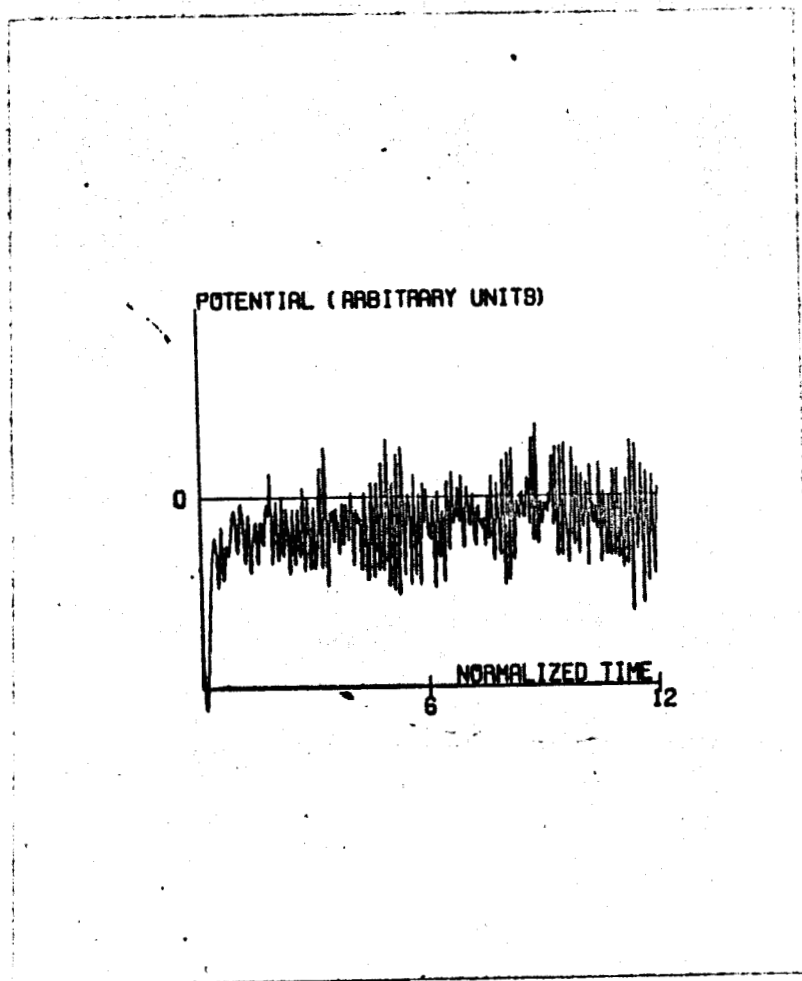


FIG. 2. POTENTIAL FLUCTUATIONS NEAR THE EMITTER
WHEN $\alpha > 1$, $\eta_2 < 0$.

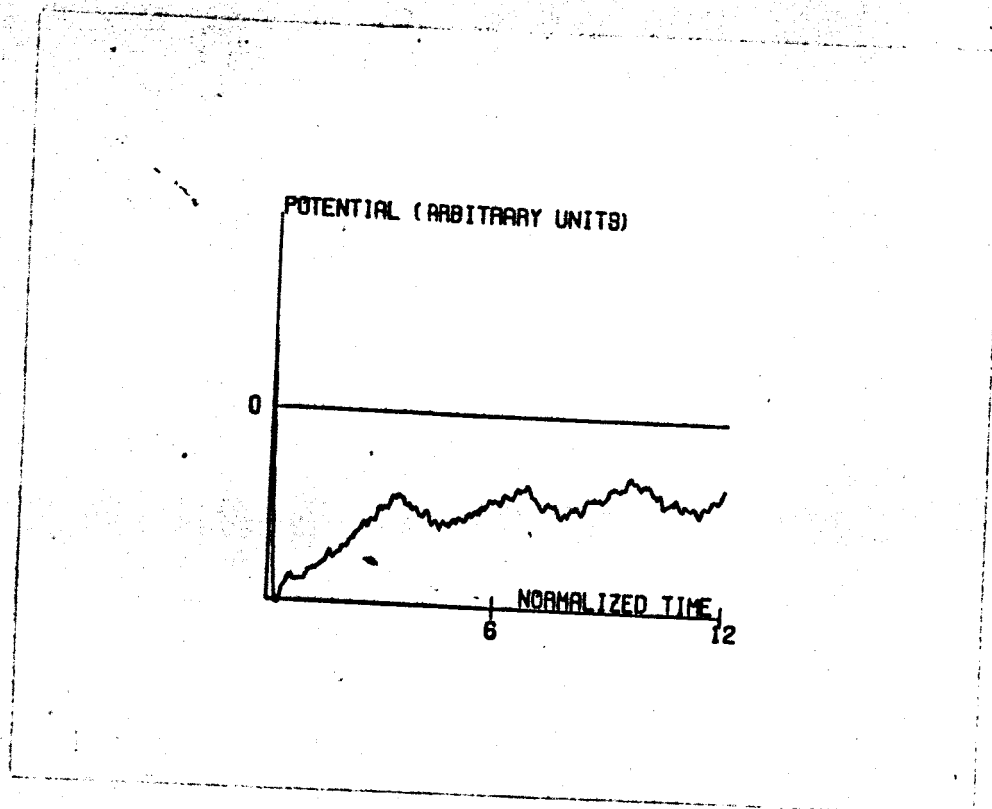
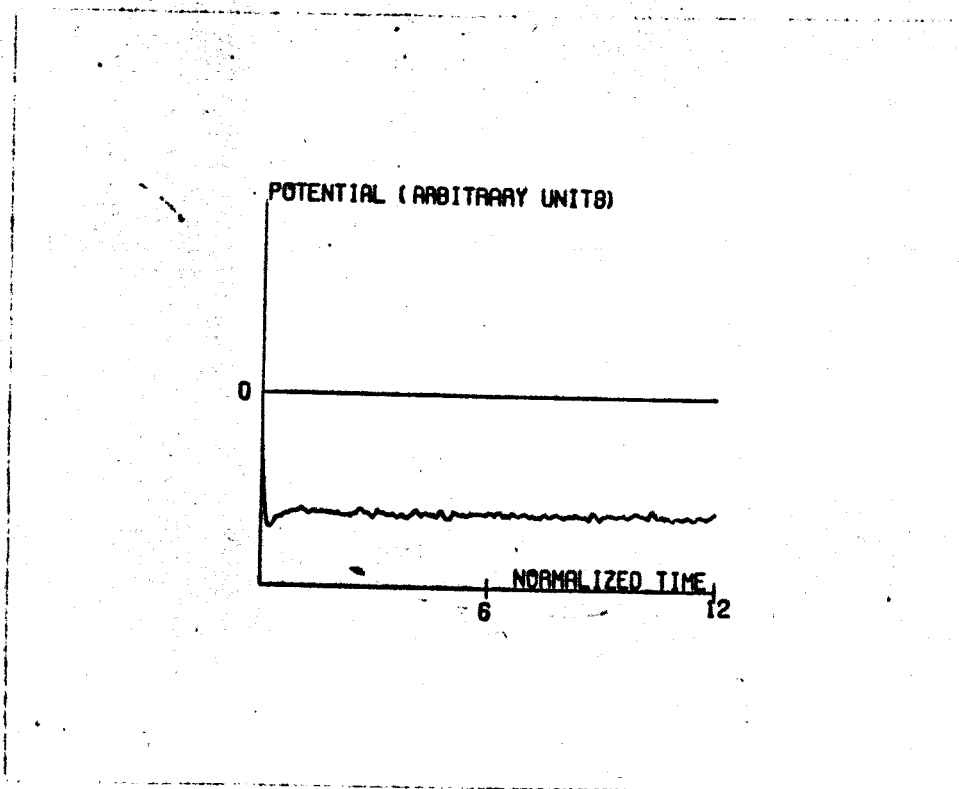


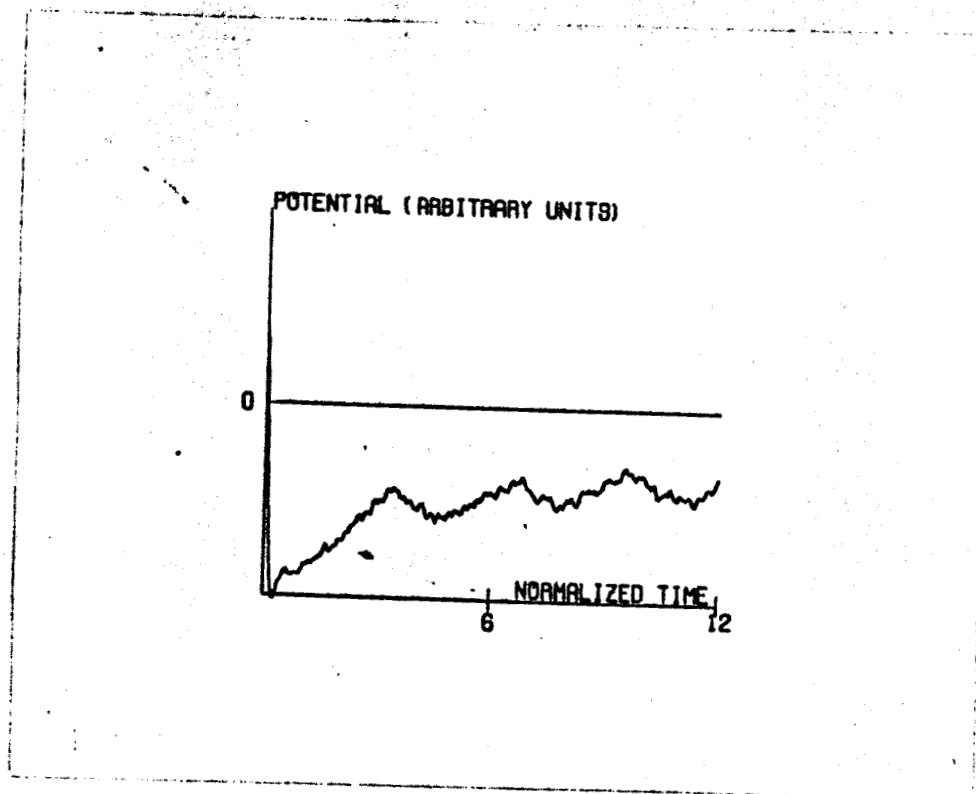
FIG. 3. POTENTIAL FLUCTUATIONS NEAR THE EMITTER
WHEN $\alpha \leq 1$, $\eta_2 > 0$.



**FIG 4. POTENTIAL FLUCTUATIONS NEAR THE EMITTER
WHEN $\alpha < 1$, $\eta_2 < 0$.**

	$\eta_2 > 0$	$\eta_2 < 0$
ION RICH	UNSTABLE (LOW FREQUENCY)	UNSTABLE (HIGH FREQUENCY)
ELECTRON RICH	STABLE	STABLE

TABLE 1. THE STABLE AND UNSTABLE REGIONS OF THE CONVERTER.



**FIG. 3. POTENTIAL FLUCTUATIONS NEAR THE EMITTER
WHEN $\alpha \leq 1$, $\eta_2 > 0$.**

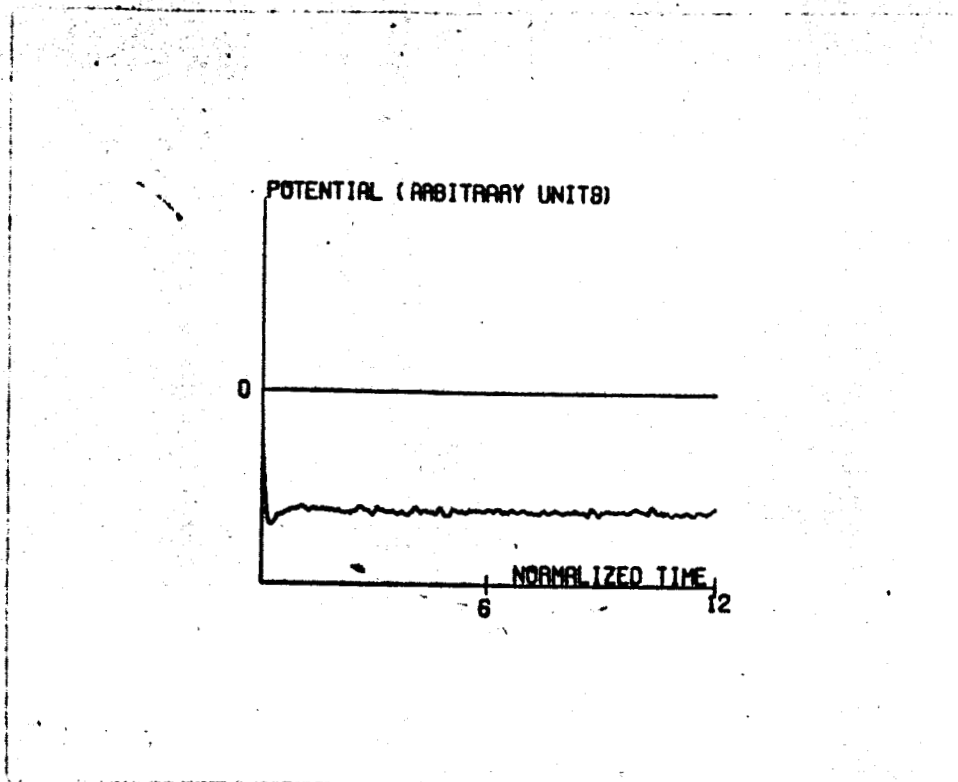


FIG 4. POTENTIAL FLUCTUATIONS NEAR THE EMITTER
WHEN $\alpha < 1$, $\eta_2 < 0$.

	$\eta_2 > 0$	$\eta_2 < 0$
ION RICH	UNSTABLE (LOW FREQUENCY)	UNSTABLE (HIGH FREQUENCY)
ELECTRON RICH	STABLE	STABLE

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